

# Update on NASA Microelectronics Activities

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# Acronyms

| Acronym  | Definition  |
|----------|---|
| 3D       | Three Dimensional                                   |
| AFRL     | Air Force Research Laboratory                       |
| AFSMC    | Air Force Space & Missile Systems Center            |
| ARM      | ARM Holdings Public Limited Company                 |
| Cadence  | Cadence Health                                      |
| CCP      | Commercial Crew Program                             |
| CoP      | Community of Practice                               |
| COTS     | Commercial Off-the-Shelf                            |
| CRÈME MC | Cosmic Ray Effects on Micro Electronics Monte Carlo |
| CREME96  | Cosmic Ray Effects on Micro-Electronics 96          |
| DDR      | Double Data Rate                                    |
| DLA      | Defense Logistics Agency                            |
| DMEA     | Defense MicroElectronics Activity                   |
| DoD      | Department of Defense                               |
| EEE      | Electrical, Electronic and Electromechanical        |
| FPGA     | Field Programmable Gate Array                       |
| GaN      | Gallium Nitride                                     |
| GPUs     | Graphics Processing Units                           |
| GRC      | NASA Glenn Research Center                          |
| GSN      | Goal Structuring Notation                           |
| HUPTI    | Hampton University Proton Therapy Institute         |
| ICs      | Integrated Circuits                                 |
| IUCF     | Indiana University Cyclotron Facility               |
| JFAC     | Navy Crane, Joint Federated Assurance Center        |
| LANL     | Los Alamos National Laboratories                    |
| LANSCCE  | Los Alamos Neutron Science Center                   |
| LET      | Linear Energy Transfer                              |

| Acronym      | Definition  |
|--------------|---|
| LLUMC        | Slater Proton Treatment and Research Center at Loma Linda University Medical Center |
| MBMA         | Model-Based Missions Assurance  |
| MDA          | Missile Defense Agency  |
| MGH          | Massachusetts General Hospital Francis H. Burr Proton Therapy                       |
| MOSFET       | Metal-Oxide-Semiconductor Field-Effect Transistor                                   |
| MRAM         | Magnetoresistive Random Access Memory   |
| NAND         | non-volatile computer memory  |
| NESC         | NASA Engineering Safety Center  |
| NRO          | National Reconnaissance Office  |
| R&M          | Reliability and Maintainability   |
| Rad-hardened | Radiation Hardened  |
| ReRAM        | Resistive Random Access Memory  |
| SCRIPPS      | SCRIPPS Proton Therapy Center   |
| SETMO        | NASA Space Environments Testing Management Office                                   |
| SiC          | Silicon Carbide   |
| SLU          | Saint Louis University  |
| SMDs         | Selected Item Descriptions  |
| SNL          | Sandia National Laboratories  |
| SOA          | safe operating area   |
| SoC          | System on a Chip  |
| STMD         | NASA Space Technology Mission Directorate   |
| ST-MRAM      | Spin-torque MRAM (ST-MRAM)  |
| SysML        | Systems Modeling Language   |
| trenchFET    | Trench Field Effect Transistor  |
| TRIUMF       | Tri-University Meson Facility   |
| UFHPTI       | University of Florida Proton Health Therapy Institute                               |



# Outline

- **Relevant NASA Microelectronics Related Entities**
- **NEPP Efforts**
- **Other NASA Efforts**
- **200 MeV Proton Update**
- **Summary**



# Relevant NASA Microelectronics “Entities”

- **NASA Electronic Parts and Packaging (NEPP) Program**
  - **Mission Statement:** *The NASA Electronic Parts and Packaging (NEPP) Program provides NASA’s leadership for developing and maintaining guidance for the screening, qualification, test. and usage of EEE parts by NASA as well as in collaboration with other government Agencies and industry.*
    - <https://nepp.nasa.gov>
- **NASA Space Technology Mission Directorate (STMD)**
  - “STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise.”
    - <https://www.nasa.gov/directorates/spacetech/home/index.html>
- **NASA Space Environments Testing Management Office (SETMO)**
  - **Mission Statement:** *The Space Environments Testing Management Office (SETMO) will identify, prioritize, and manage a select suite of Agency key capabilities/assets that are deemed to be essential to the future needs of NASA or the nation, including some capabilities that lack an adequate business base over the budget horizon.*
    - <http://scap.hq.nasa.gov/>
- **NASA Engineering Safety Center (NESC)**
  - **NESC mission is to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success.**
    - NASA Space Environments and Avionics Fellows as well as Radiation and EEE Parts Community of Practice (CoP) leads
    - <https://www.nasa.gov/offices/nesc/home/index.html>



# Sample NEPP Agency Collaborations

| Topic  | Agency(ies)   | Description   |
|--|---|---|
| 3-D Integrated Circuits (ICs)                    | AFSMC, DMEA, AFRL, NRO, Missile Defense Agency (MDA), Navy Crane  | Working Group to explore future assurance for commercial and military 3D (ICs).                           |
| Advanced processors and Systems on a Chip (SOCs) | Navy Crane  | Radiation evaluation of advanced technology microprocessors and SOC's..                                   |
| Advanced Non-Volatile Memories                   | Navy Crane  | Radiation and reliability evaluation of advanced technology, non-volatile memories                        |
| Audits, Manufacturer and Test Houses             | Defense Logistics Agency (DLA), Air Force Space & Missile Systems Center (AFSMC)                          | Joint audits of EEE parts manufacturers and test houses relevant to NASA needs                            |
| Automotive Electronics                           | Navy Crane, AFSMC   | Evaluation of reliability of automotive electronics for space considerations.                             |
| FPGAs- Microsemi                                 | AFSMC   | Independent radiation testing of new radiation tolerant FPGA from Microsemi.                              |
| FPGAs - Xilinx                                   | Sandia National Laboratories (SNL), Los Alamos National Laboratories (LANL)                               | Team for independent radiation evaluation of next generation Xilinx "space product" FPGA                  |
| Military Electronics Qualification Review        | Defense Logistics Agency (DLA), Air Force Space & Missile Systems Center (AFSMC)                          | Review of proposed changes to MIL specs and standards as well as (SMDs), etc...                           |
| NEPP Radiation Testing                           | AFSMC   | Cooperative effort with Air Force SMC   |
| Proton Radiation Test Facilities                 | AFSMC, National Reconnaissance Office (NRO)   | Team evaluation of options for proton testing now Indiana University Cyclotron Facility (IUCF) is closed  |
| Radiation Test Facility Infrastructure Study     | AFSMC, DOE  | Study by National Academies of Science to review aging test facility etc.                                 |
| Trusted Foundry and Trusted FPGAs                | AFSMC, DMEA, AFRL, NRO, Missile Defense Agency (MDA), Navy Crane, Joint Federated Assurance Center (JFAC) | Supporting DoD studies on the future for trusted electronics and foundry access.                          |
| Trusted FPGA                                     | AFSMC, DMEA, AFRL, NRO, Missile MDA, Navy Crane, JFAC   | Supporting DoD funded effort for development of new trusted product.                                      |
| Widebandgap Working Group                        | High Reliability Virtual Electronics Center (HiREV) – AFRL, DMEA, NRL                                     | Coordinated efforts in radiation and reliability work on both GaN and SiC widebandgap technology devices. |

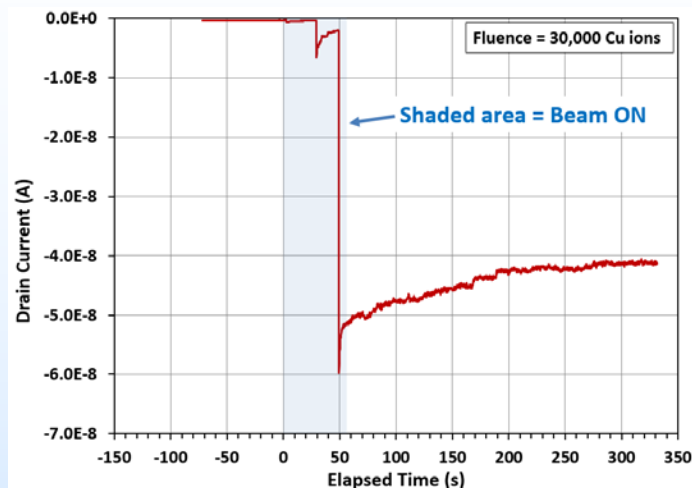


# NEPP – Selected Evaluation Plans

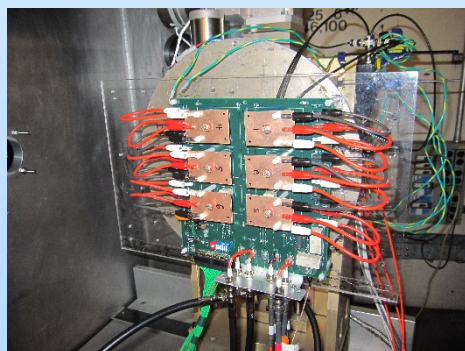
- **FPGAs**
  - Microsemi RTG4 and Xilinx Ultrascale+ (FY17)
  - Altera Stratix 10 (FY18)
- **Memories**
  - Fujitsu 45nm ReRAM (Foundry: TowerJazz Panasonic Semiconductor Co. – TPSCo)
  - Spin-torque MRAM (ST-MRAM) – Everspin/Avalanche (TBD)
    - Keeping an eye on GlobalFoundries
  - 3D NAND and other advanced FLASH
  - DDR3/DDR4
- **Processors**
  - Radiation hardened
    - BAE RAD5510/5545, Vorago ARM
  - Commercial
    - Sub 20nm (Samsung, Intel)
    - GPUs (Nvidia, TBD)
- **Widebandgap**
  - GaN and SiC commercial devices



# Silicon Trench Power MOSFET Response to Heavy Ion SEE



**TrenchFET™ drain current during beam run: 0 V applied to all pins**



**Rad-hardened trench MOSFETs on test board at LBNL**

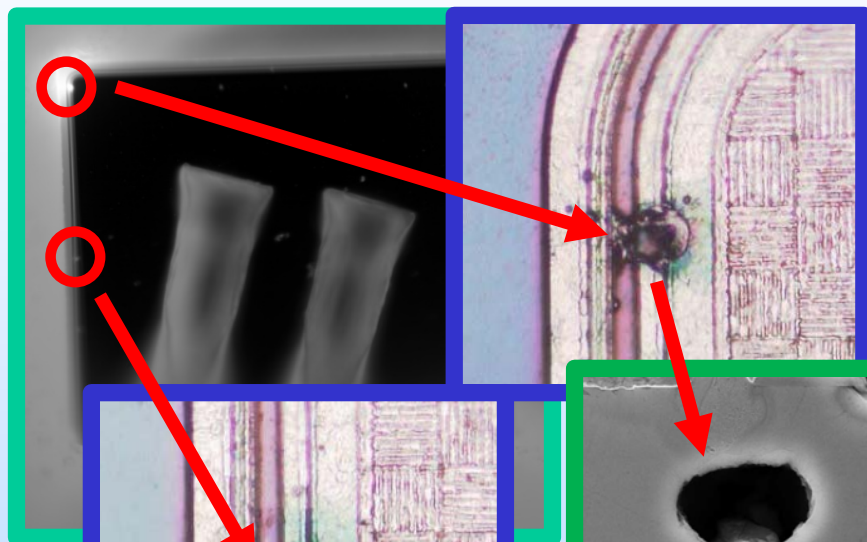
- **Unexpected vulnerability to a automotive-grade trenchFET™ with all pins grounded**
  - Copper-ion induced drain-current spike resulting in 3-order of magnitude increase in drain-source leakage current post-rad
  - **Implications for on-orbit vulnerability during unpowered phase or to spares?**
  - Investigations in partnership with NESC
- **First (and only) rad-hardened trench MOSFET: Manufacturer SEE safe operating area (SOA) verified**
  - No measurable effects inside the SOA
  - **3 different failure signatures occurred outside SOA**
    - Greater complexity than planar MOSFETs



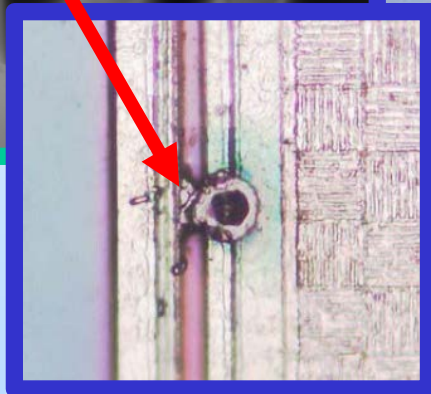


# Failure Analysis of Heavy-Ion-Irradiated Diodes

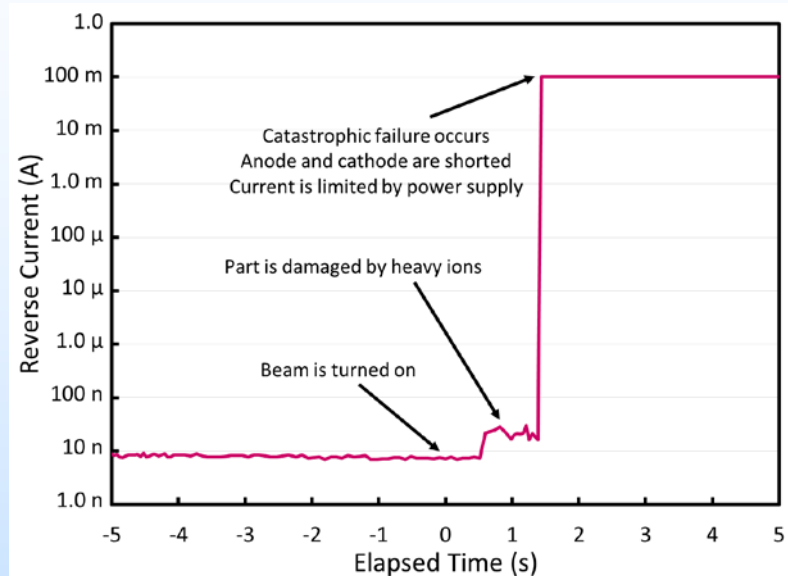
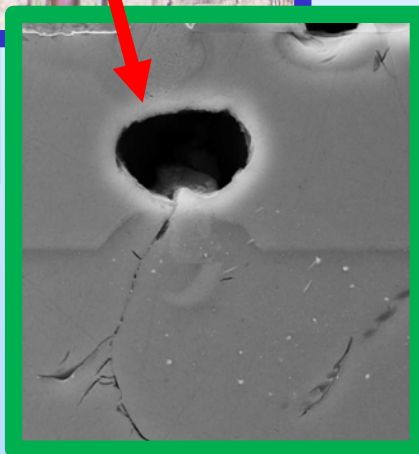
Thermal Image of failure locations



High magnitude optical images of failure locations

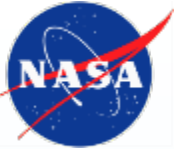


Cross-section of failure location



- Diodes Inc. SBR20A300 300 V, 20 A Super Barrier Diode
- Experienced **catastrophic failure** when reverse biased at 225 V and irradiated with 1233-MeV Xe ( $\text{LET} = 58.8 \text{ MeV-cm}^2/\text{mg}$ ) at LBNL
- After failure, breakdown voltage reduced from 331 V to 1 V and forward voltage reduced slightly





# NEPP and Small Missions/ Alternate “Assurance” Approaches

- **Sample Current Efforts**
  - Radiation Hardness Assurance for Small Missions (Best Practices)
  - Root Cause Analysis and Success Tracking of CubeSats (Prof. Michael Swartwout/SLU) – we’re looking for possible low hanging fruit for university-class CubeSats
  - Model-Based Missions Assurance (MBMA) for CubeSats:
    - 1st task is a Goal Structuring Notation (GSN) exemplar of a CubeSat board – this is joint with the NASA Reliability and Maintainability (R&M) Program
    - FY17 follow-on adds Bayesian Methods/SysML
  - Board-level proton test guideline
  - Automotive grade EEE parts
  - CubeSat parts database – both kit manufacturers and usage within NASA
    - Have formed a small working group on sharing information
  - Multiple COTS evaluation tasks relevant to CubeSats
- **Future considerations**
  - COTS, COTS, COTS (and alternate grade electronics)
  - EEE Parts Best Practices for Small Missions
  - Board level testing for EEE parts assurance?



# NASA STMD

- **Relevant efforts**
  - **High Performance Spacecraft Computing (HPSC)**
    - The goal of the HPSC activities is to develop a significantly improved spaceflight computing capability for NASA missions. This will be achieved by addressing the computational performance, energy management, and fault tolerance needs of NASA missions through 2030.
    - Currently in procurement silence for proposal selection process. (Partner with AFRL).
    - <https://gameon.nasa.gov/projects-2/high-performance-spaceflight-computing/>
  - **Advanced Memory Technology**
    - Initial manufacturing status and usage studies for advanced memory technologies relevant to HPSC needs.
    - Expectations for collaborative testing with NEPP Program.



# NASA “Other”

- **NASA SETMO**

- Along with NEPP and NASA Space Environments Fellow, SETMO is exploring NASA “common buys” of radiation test facilities (proton, heavy ion).
  - This allows NASA to internally prioritize access to the facilities as well as provide possible support to critical facilities.

- **NESC**

- Along with NEPP is supporting or evaluating:
  - Independent review of NASA’s Commercial Crew Program (CCP),
  - Automotive-grade electronics, and,
  - Board/assembly level EEE parts testing.



# Proton Facilities – 200 MeV regime

## Prime Proton Research Facilities

- Massachusetts General Hospital (MGH) Francis H. Burr Proton Therapy Center
  - Provides 24 hours for 3 out 4 weekends a month
  - Highly used by industry and all Agencies
    - Overbooked already for CY17!
    - Limited availability for NASA
- Tri-University Meson Facility (TRIUMF) – Vancouver, CAN
  - Runs 4 cycles a year

## • Proton Cancer Therapy Facilities Taking Customers

- Loma Linda University Medical Center (LLUMC)
  - Weekend usage with limited available time beyond current load
- SCRIPPS Proton Therapy Center
  - Some weekend access
  - Has 4 industry user contracts with no additional users (i.e., “large” users only – 100 hrs/yr)
- Hampton University Proton Therapy Institute (HUPTI)
  - Planning to open research room in Mar-Apr 2017
    - NEPP and OneWeb supporting planning
    - Visit in 2Q FY17 to review and discuss
  - Beam will be DURING the week (no weekends)
    - Interleave with patients (~10 min access per hour)
  - Hourly costs - TBD
    - Seeking individual user contracts similar to SCRIPPS mode, but may be more flexible
- Northwestern Chicago Proton Center (former Cadence)
  - Possibly reopening for customers
  - NASA biological dosimetry folks have gone there recently and NEPP has tentative 3/4/17 date

## • Proton Cancer Therapy Facilities – Pending Access

- U MD Proton Therapy Center (Baltimore)
  - Completing medical commissioning by summer of CY17 – shakeout test in CY17
  - Planning similar mode to SCRIPPS
- University of Florida Proton Health Therapy Institute (UFHPTI)
  - Completing medical commissioning
  - TBD yearly hours available to community but expect ~300 hours/year
  - Expect shakeout test in 4Q FY17
- Case Western University Hospital Seidman Cancer Center
  - NASA GRC working a SAA with expected visit?
    - Waiting on lawyers
  - Small facility with expected limited hours (but great for GRC!)
- Mayo Clinic
  - Two proton facilities (Rochester, MN and Phoenix, AZ)
    - Visited in 1QFY17
    - Research room built and have experience with government contracts
    - Shakeout test expected in 2Q FY17
- ProVision (Knoxville)
  - TBD – 2 rooms opening with TBD excess capacity in TBD timeframe in 2017 – limited responsiveness

## • Proton Research Facilities – Proposals

- Los Alamos Neutron Science Center (LANSCE)
  - Has 800 MeV proton source with white paper to modify for SEE test purposes
  - Visited in 1QFY17 – requested support and aid in obtaining funding
  - Question remains on beam structure

## Note:

**There are other proton cancer therapy centers, but they have either expressed no interest or have stopped access due to business/financial or other concerns**



# Summary and Comments

- **NASA activities are constantly evolving as technology and products become available.**
  - Like all such efforts, NEPP is limited by funding and resource availability.
    - Many other efforts are not being shown today (60+ NEPP tasks total)
    - Note: CREME96 website operations is funded by NEPP (but not improvements nor CRÈME MC)
  - Partnering is the key:
    - Government,
    - Industry, and,
    - University.
- **We look forward to further opportunities to partner and hope to see you at our workshop June 19-22, 2017.**  
***<https://nepp.nasa.gov>***